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[54] **TOOL FOR TUNING MICROWAVE CIRCUIT WITHIN A CLOSED HOUSING**

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[73] Assignee: **Raytheon Company**, Lexington, Mass.

[21] Appl. No.: **572,071**

[22] Filed: **Jun. 29, 1990**

[51] **Int. Cl.**[5] **G01R 1/06**; G01R 31/02; G01R 1/38

[52] **U.S. Cl.** .... **324/158 P**; 324/74; 324/157 F

[58] **Field of Search** .... 324/158 P, 158 F, 72.5, 324/95, 74; 200/530, 532, 540

[56] **References Cited**

U.S. PATENT DOCUMENTS

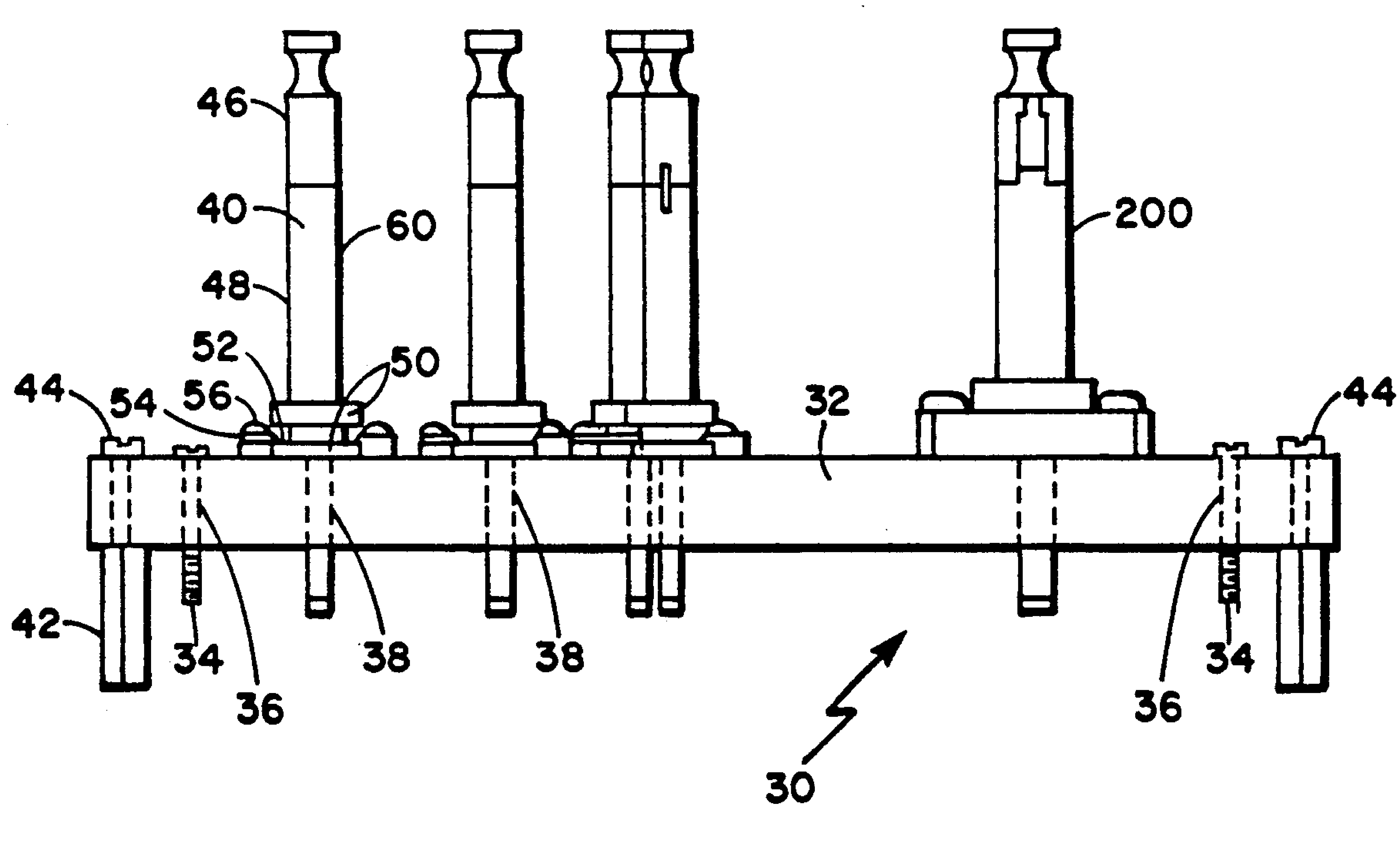
3,950,627 4/1976 Murata et al. 200/530
4,596,912 6/1986 Hattori 200/530
4,818,828 4/1989 Curley et al. 200/532

Primary Examiner—Ernest F. Karlsen
Attorney, Agent, or Firm—Christopher L. Maginniss; Richard M. Sharkansky

[57] **ABSTRACT**

A production circuit tuning tool consisting of a cover and a number of feed-through, gold-tipped probes that adjust the performance of an underlying circuit. The probes are positioned in the cover so that they may act as temporary jumpers between the trace wiring and tuning patches on the circuit substrate. The portion of the probe that bridges the patches comprises a slender nonconductive plunger of low dielectric constant material having a gold plated tip. Once the proper combination of jumpers is determined, the tuning tool cover is removed, permanent jumpers are soldered into place and a regular production cover is installed.

13 Claims, 5 Drawing Sheets



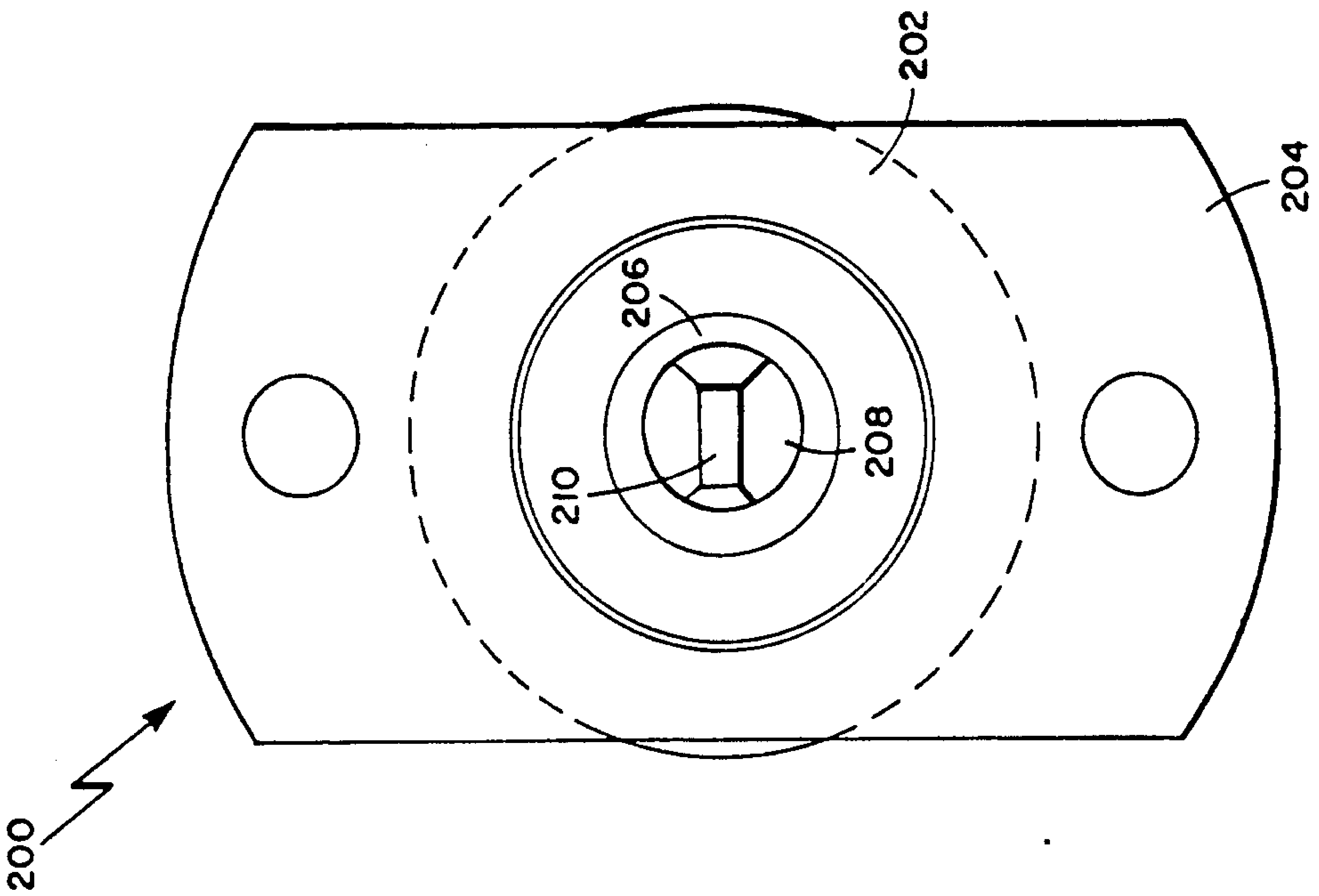
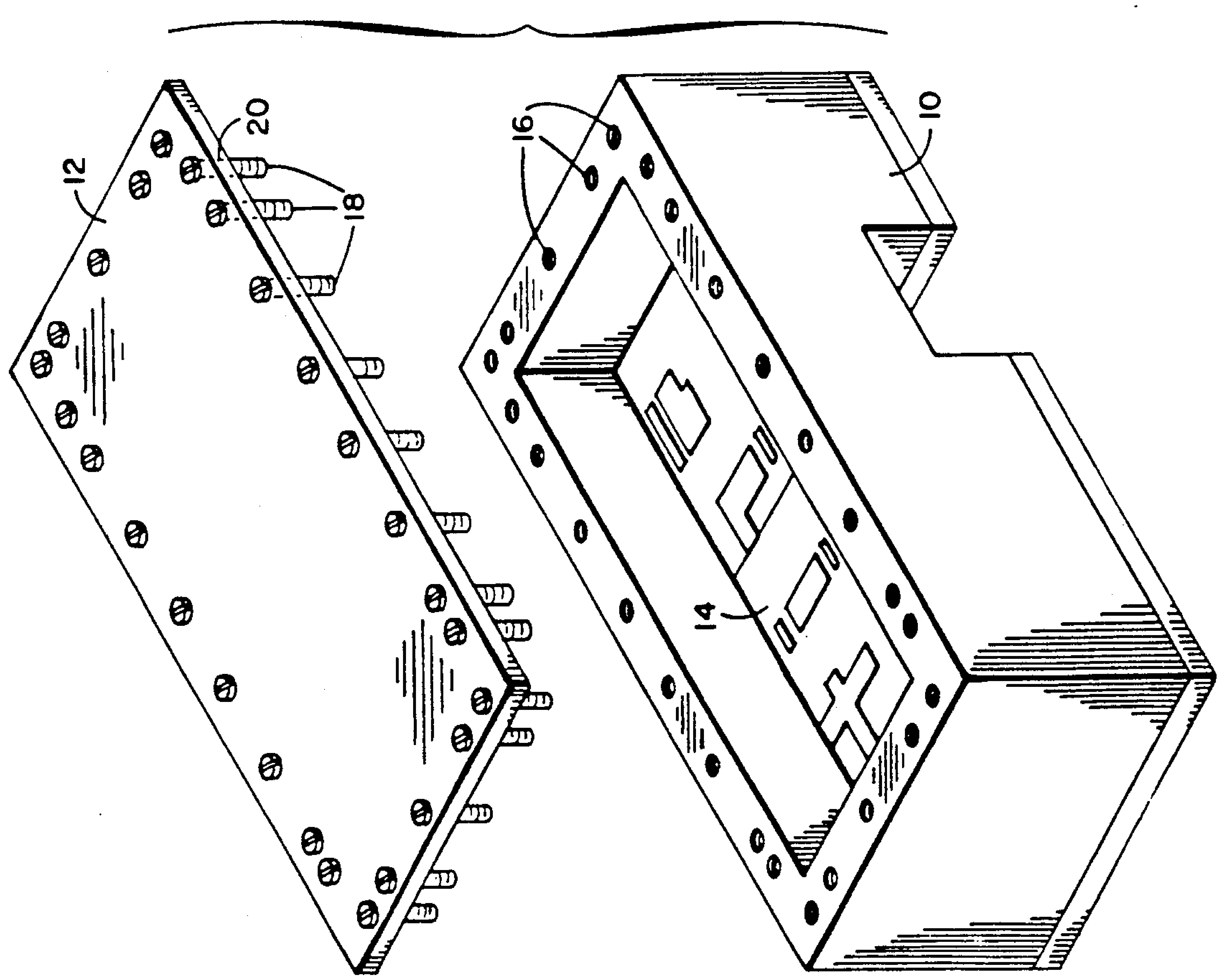


Fig. 6

Fig. 1



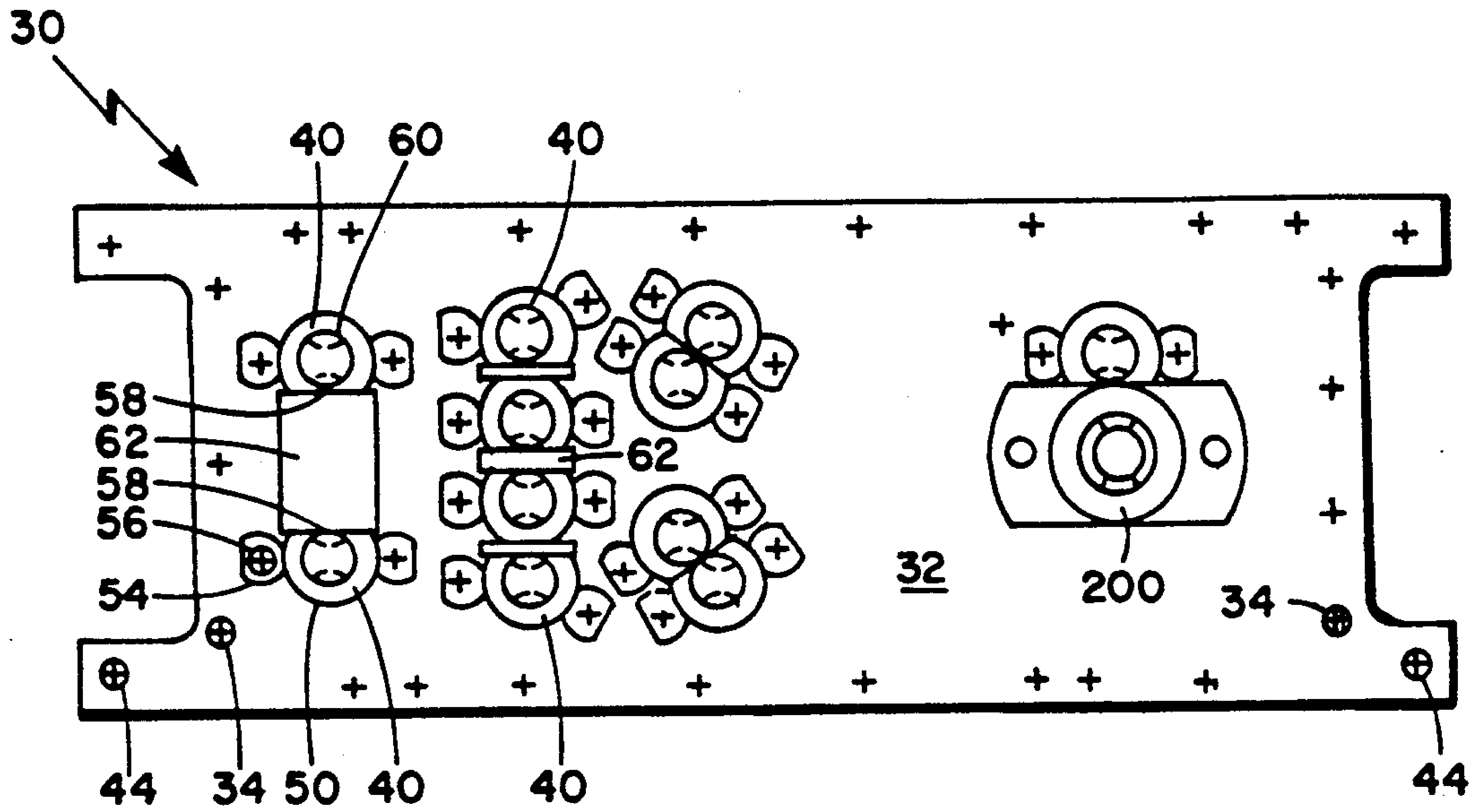

30
40
60
40
58
62
58
56
54
62
32
200
34
44
34
50
40
40
44

Fig. 2

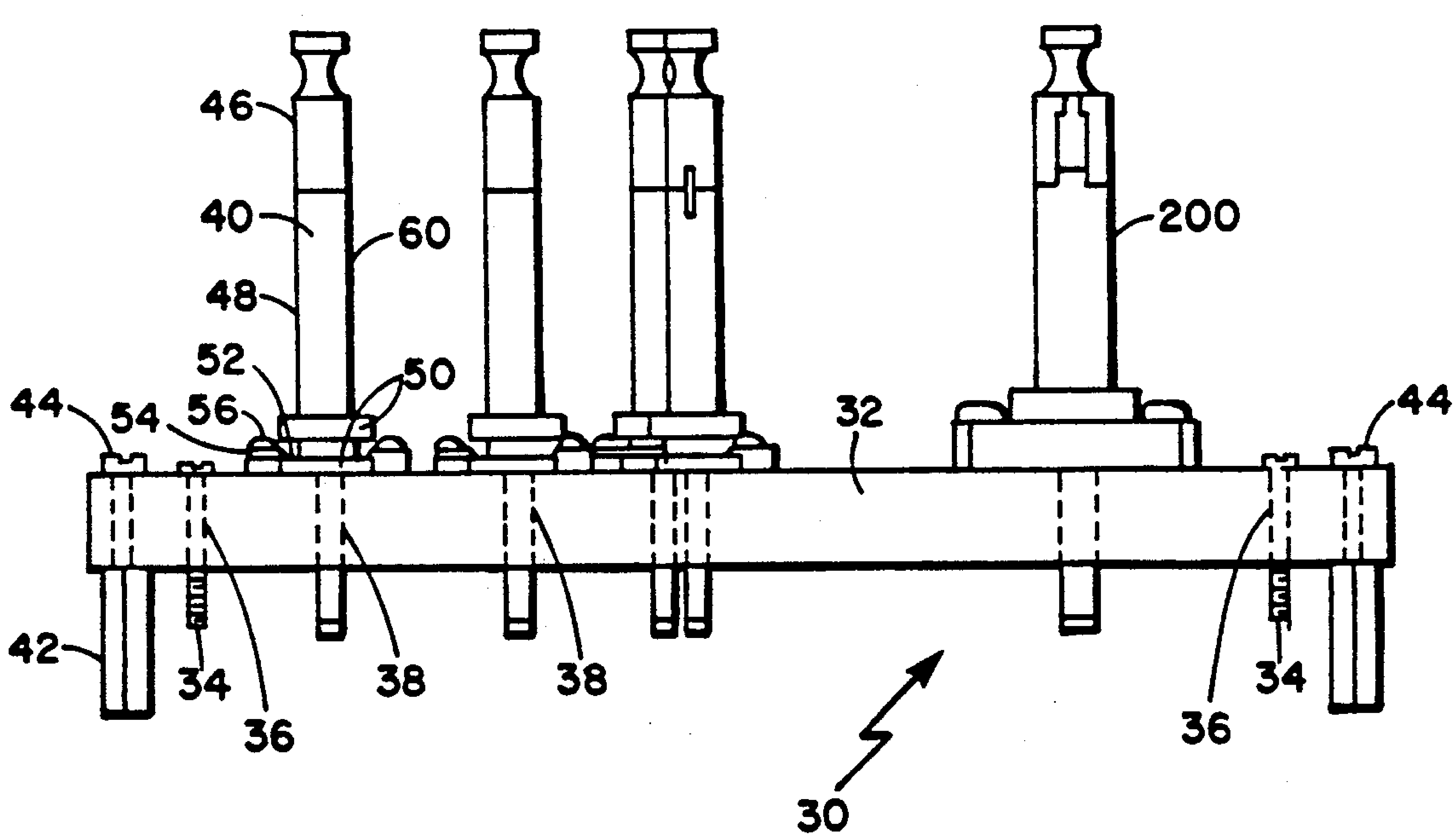

46
40
60
48
52
50
44
54
56
32
200
44
42
34
36
38
38
36
34
30

Fig. 3

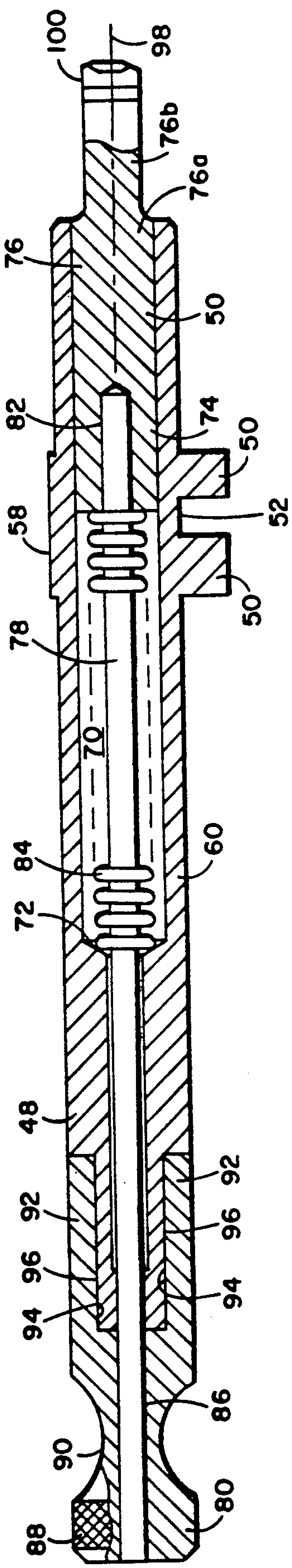

100
98
76b
76a
76
50
82
74
50
58
52
50
78
70
84
60
72
48
92
92
96
96
94
94
86
90
80
88

Fig. 4

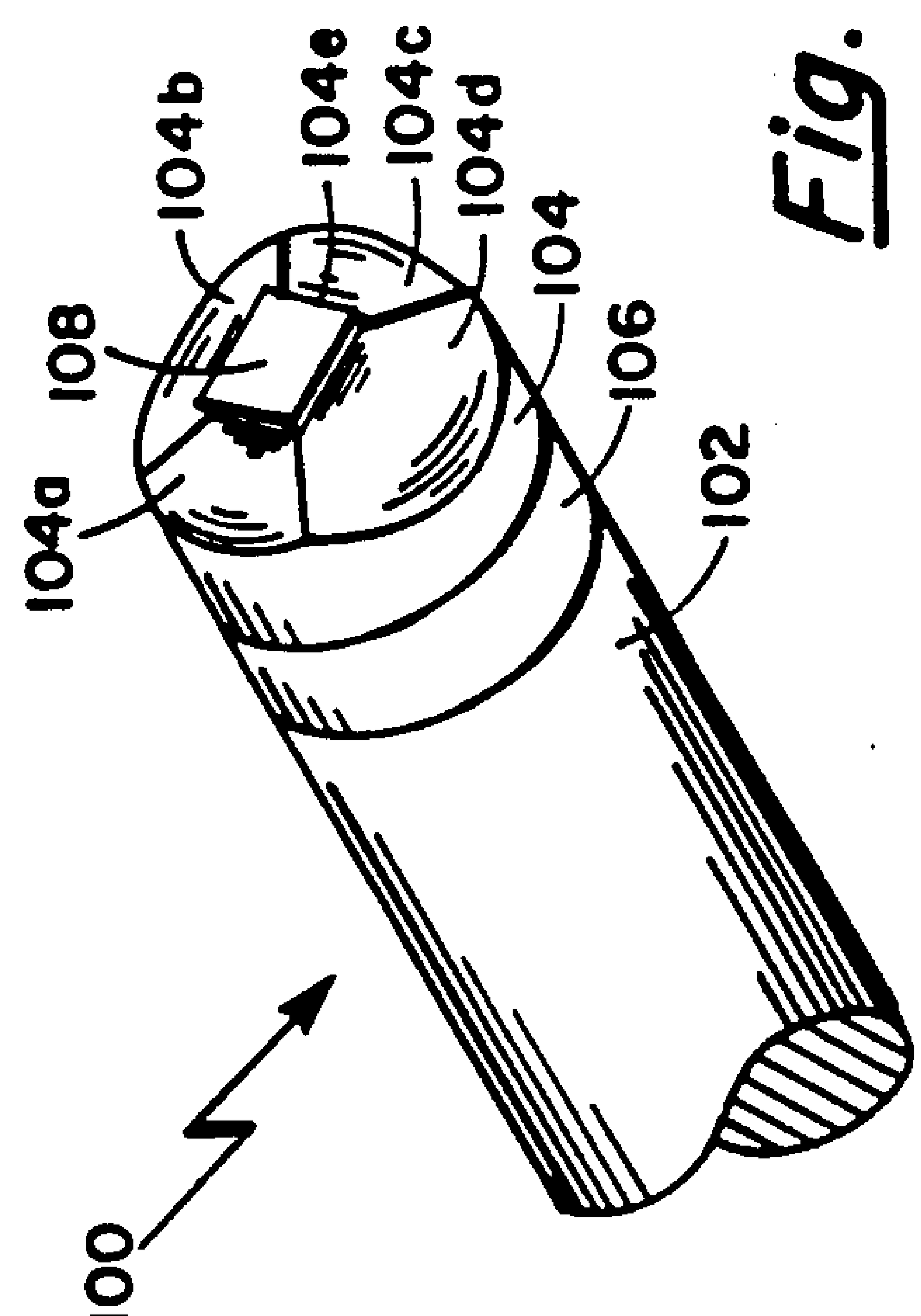

104b
104e
104c
104d
108
104
106
104a
102
100

Fig. 5

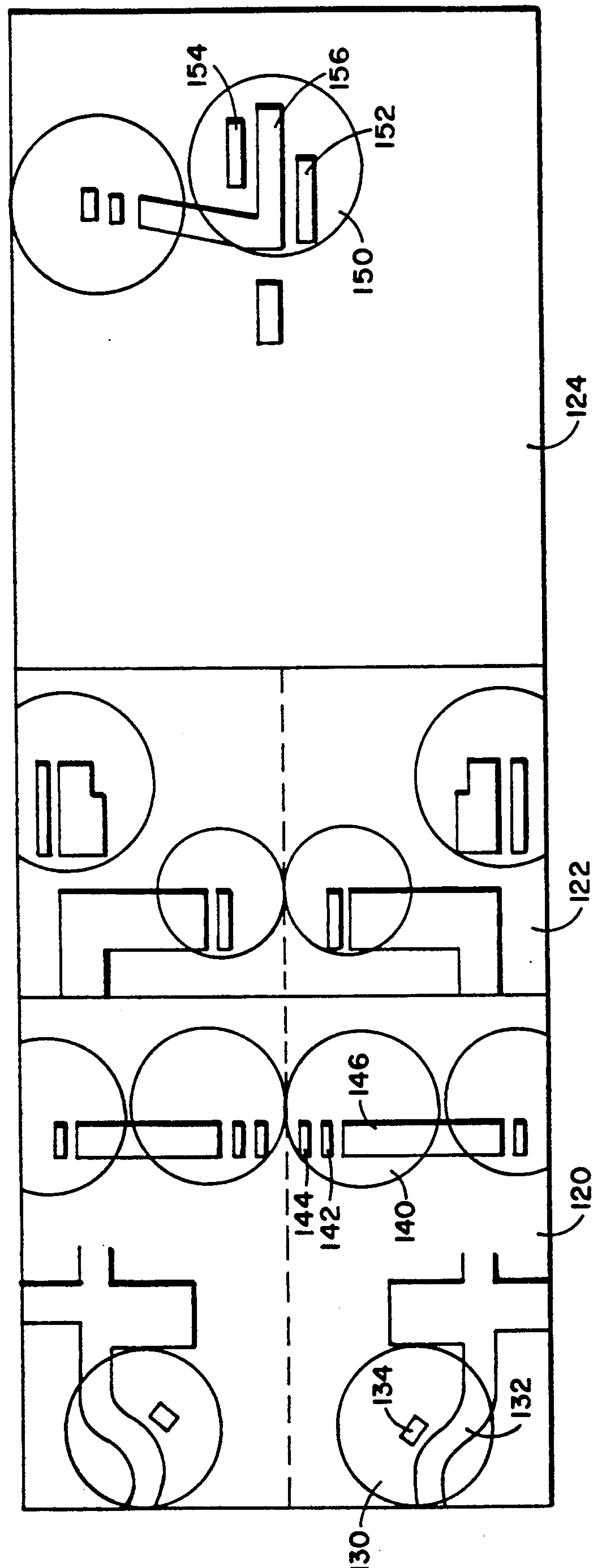


Fig. 7

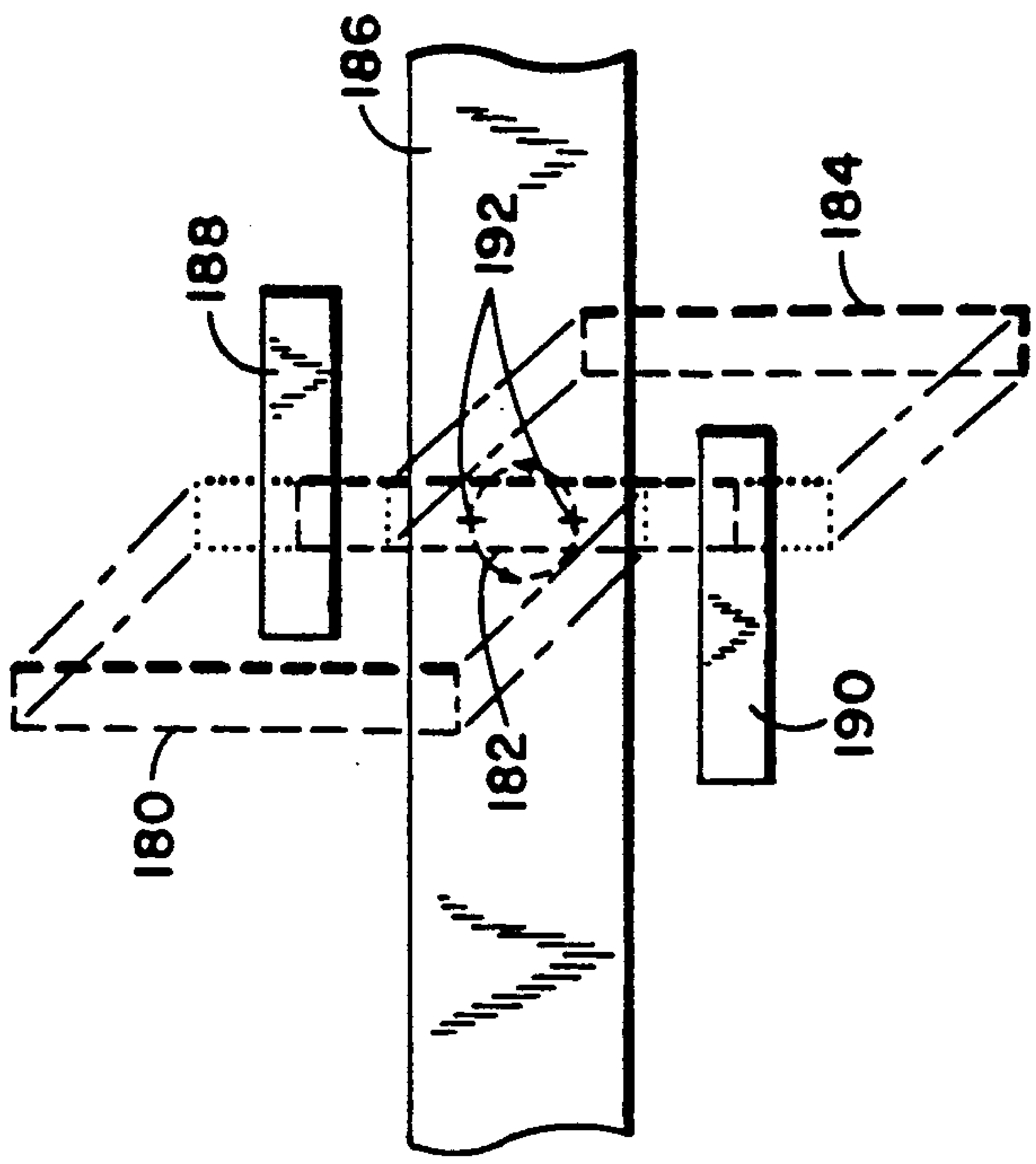


Fig. 8C

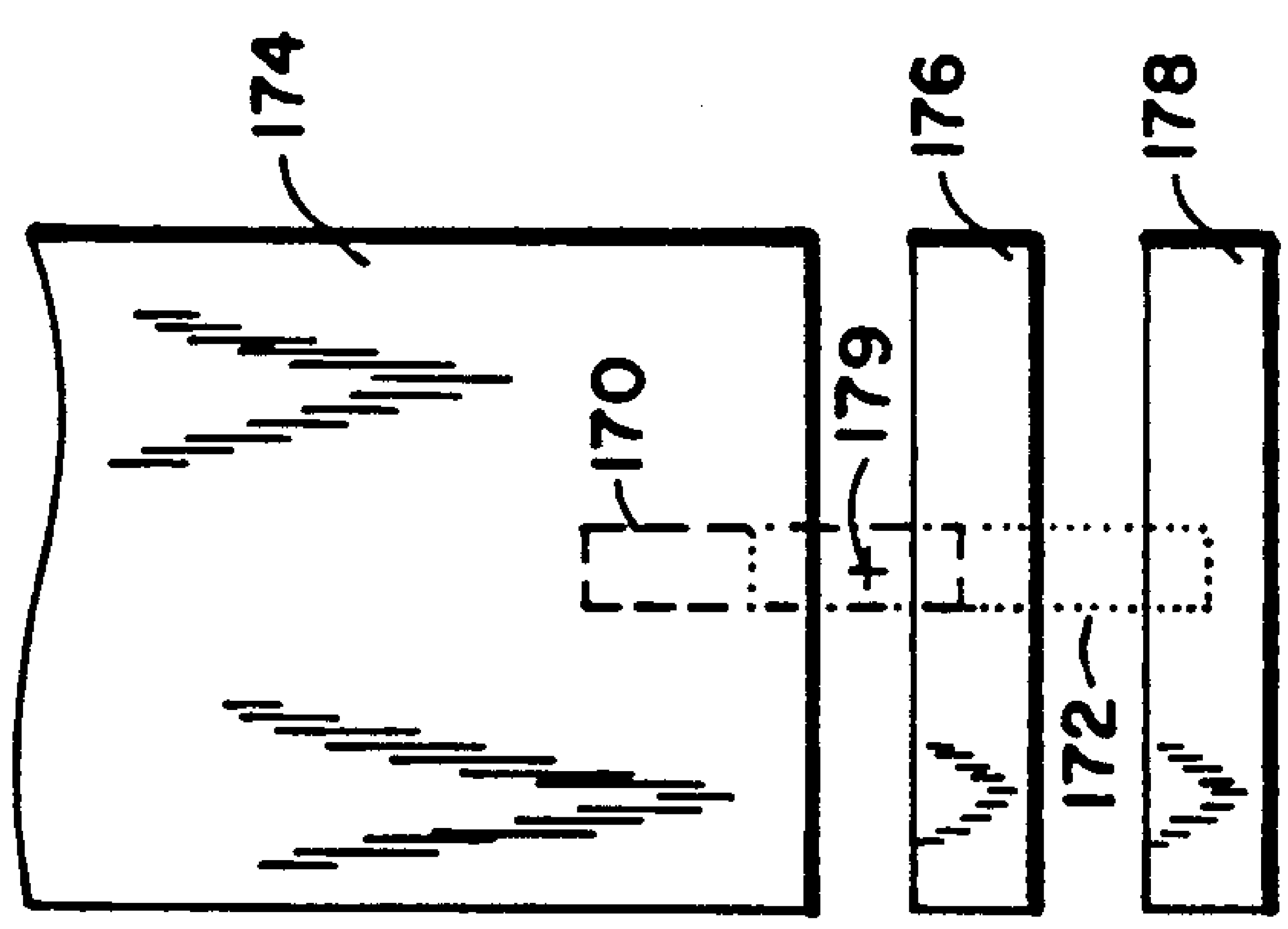


Fig. 8B

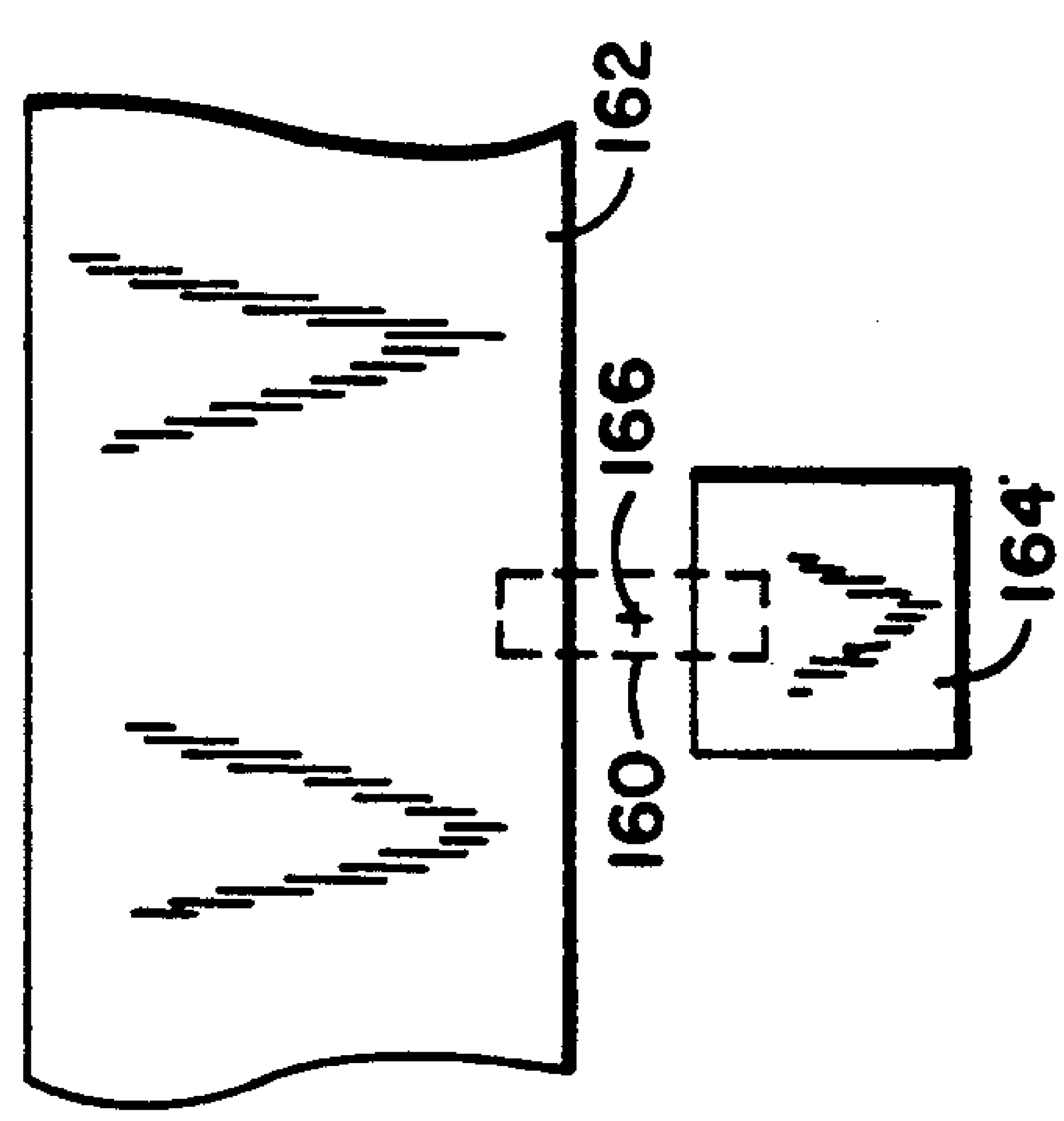


Fig. 8A

TOOL FOR TUNING MICROWAVE CIRCUIT WITHIN A CLOSED HOUSING

The Government has rights to this invention pursuant to Contract No. DAAH01-87-C-A025, awarded by the Department of the Army.

BACKGROUND OF THE INVENTION

The present invention relates generally to microwave circuits and, more particularly, to an assembly for covering a housing which encloses a microwave circuit, wherein the cover assembly includes externally-accessible probes for providing tuning of the microwave circuit while the cover assembly is in place on the housing.

A typical microwave hybrid integrated circuit (MHIC) module may comprise a plurality of ceramic substrates, the substrates including resistive, capacitive and active components soldered to a surface and further including gold circuit traces deposited on a polished surface for interconnecting the components. The component-mounted substrates are typically mounted side by side in an aluminum housing, interconnected by gold jumper wires and enclosed within the housing via an aluminum cover. At the microwave frequencies of interest, the geometry of the gold circuit paths on the substrates, and their locations with respect to each other and to the surrounding housing (particularly including the cover), creates inductive and capacitive effects.

The total assembly, including the component-mounted substrates within the housing, is tuned for gain and "noise figure" over the frequency band of interest. This tuning may typically be accomplished by connecting jumper wires from the main circuit traces to small tuning patches adjacent a trace path or at the end of a branch. Although the tuning patches are quite small, illustratively 0.02 in. (0.5 mm) by 0.06 in. (1.5 mm), they have a significant influence on the performance of the circuit when they are connected, by slightly increasing the area or length of the associated trace.

Unfortunately, the subsequent installation of the cover on the aluminum housing after the above-described tuning procedure has a far greater impact on circuit performance than the interconnection of the internal tuning patches and jumpers. Clearly, the cover must be in place before the assembly can be finally tested, but the presence of the installed cover would ordinarily preclude further adjustment, as it covers the circuits.

It has been the practice in the past to make educated guesses regarding the soldering of tuning patches to the circuit traces during a series of iterations involving the affixing of the cover, testing for the above-described gain and noise parameters, and removal of the cover. This time-consuming procedure may be further exacerbated by a large number of cover screws, all of which must be completely in place before the electrical testing may be performed with accuracy. It is not unusual to find that an average of eight such tuning iterations are required for each MHIC module before it meets its electrical specification.

Clearly, this form of iterative tuning procedure creates a bottleneck in any circuit production facility. What is required is a real-time procedure for tuning the circuits via jumpers to the tuning patches while in an environment which accurately simulates the enclosed housing.

SUMMARY OF THE INVENTION

It is therefore a primary object of the present invention to provide a means for tuning a microwave circuit within an environment simulating an enclosed housing.

It is a further object of the present invention to provide a tool for enabling electrical tuning adjustments to a microwave circuit within a closed housing.

It is a still further object of the present invention to provide a tuning cover for enclosing a housing containing microwave circuits, wherein the tuning cover includes externally-accessible means for making tuning adjustments to the microwave circuits.

These and other objects of this invention are obtained generally by providing a cover assembly for enclosing a housing which contains a printed wiring circuit board. The cover assembly comprises a cover plate adapted for covering the housing, the cover plate having an aperture therethrough, and a probe extending through the aperture, the probe having an electrically conductive tip, the probe being movable between an extended position and a retracted position. The extended position of the probe locates the conductive tip in electrical contact with a printed wiring trace of the circuit board, while the retracted position of the probe withdraws the conductive tip away from the circuit board.

In a preferred embodiment of the present invention, the cover assembly includes a plurality of probes extending through a corresponding plurality of apertures in the cover plate. The plurality of probes may include a first type of probe which provides a single extended position, connecting a printed wiring trace to a patch; a second type of probe which provides two extended positions, selectively connecting either of two patches to a printed wiring trace; and a third type of probe which provides three extended positions, selectively connecting either or both of two patches to a printed wiring trace.

With this arrangement it is possible to tune a microwave circuit within an enclosed housing by the use of a tuning cover assembly which accurately simulates the actual housing cover.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the present invention will be more fully understood from the following detailed description of the preferred embodiment, the appended claims, and the accompanying drawings, in which:

FIG. 1 illustrates a typical microwave circuit module housing shown with a conventional housing cover;

FIGS. 2 and 3 are plan and side views, respectively, of the tuning cover assembly according to the present invention;

FIG. 4 is a partly cutaway view of a probe for use in the tuning cover assembly of FIGS. 2 and 3;

FIG. 5 is a magnified view of the tip of the probe illustrated in FIG. 4;

FIG. 6 is a bottom view of a modified probe for use in the tuning cover assembly of FIGS. 2 and 3;

FIG. 7 is a plan view of a microwave circuit module including tuning patches for use with the tuning cover assembly of FIGS. 2 and 3; and

FIG. 8a, 8b and 8c illustrate how the tuning cover assembly of FIGS. 2 and 3 is used to interconnect microwave circuit traces with one or more tuning patches.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, there is shown a microwave circuit module housing **10** shown detached from its conventional cover **12**. Housing **10** contains therein a printed wiring circuit module **14** and includes, along its periphery, a plurality of threaded apertures **16**. Cover **12** is securely affixed to housing **10** via a corresponding plurality of screws **18** which extend through apertures **20** in conventional cover **12** into threaded apertures **16**. The present invention relates to a tuning cover assembly which temporarily replaces conventional cover and thereby enables an initial circuit adjustment process of tuning the microwave circuit module **14** for gain and noise figure over a range of frequencies.

FIGS. **2** and **3** are plan and side views, respectively, of the tuning cover assembly **30** of the present invention for use with the microwave hybrid integrated circuit housing **10** of FIG. **1**, replacing conventional cover **12** during the circuit tuning process. Cover assembly **30** includes a cover plate **32**, illustratively fabricated of aluminum hard-coated with nickel; fastening means **34**, illustratively a plurality of machine screws, for attaching cover plate **32** through apertures **36** along the periphery thereof to corresponding threaded apertures **16** in the microwave circuit housing **10** (not shown); and a plurality of probes **40** (twelve are illustrated) extending through apertures **38** in cover plate **32**. Also attached to cover plate **32** are four feet **42**, illustratively attached via screws **44**. Feet **42**, which extend from the bottom surface of cover plate **32** beyond the extended lengths of the tips of probes **40**, protect the probe tips from incidental, potentially-injurious contact while cover assembly **30** is not attached to the microwave circuit housing.

Probes **40** each include a movable, spring-loaded plunger **46** within a stationary probe housing **48**. Probe housing **48** comprises a tubular member **60**, typically fabricated of stainless steel, with a mounting flange **50** and a locating pilot **58**. Probes **40** are held securely to cover plate **32** via cams **54** which engage a recess **52** in flange **50**; cams **54** are held to cover plate **32** by screws **56**. Locating pilots **58** comprise flat surfaces in probe housing **48** which mount flush against pilot alignment structures **62** on cover plate **32** or which mount flush against the locating pilot **58** of an adjacent probe **40**.

Referring to FIG. **4**, there is shown a partially cross-sectional view of probe **40**, which may be similar to any one or more of the probes of FIGS. **2** and **3**. Probe **40** includes a generally cylindrical tubular probe housing **48** which is illustratively fabricated of stainless steel. Housing **48** includes mounting flange **50** and locating pilot **58**; their function for attachment of probe housing **48** to cover plate **32** was described in the preceding paragraph. A central bore **70** through housing **48** includes a shoulder **72** where there is a change in diameter of central bore **70**.

Probe **40** additionally includes plunger **74** which is capable of longitudinal and rotational movement within the central bore **70** of housing **48**. Plunger **74** comprises three elements: a tip portion **76**, a control rod **78** and a cap **80**.

Tip portion **76** comprises a rod having a first cylindrical section **76*a*** of a first diameter, stepped down to a second cylindrical section **76*b*** of a second diameter. In the present example, tip portion **76** is fabricated of alumina and is 0.885 in. (2.25 cm) in length; the diameter of the first section 76*a* is 0.188 in. (4.78 mm) and the diameter of the second section **76*b*** is 0.125 in. (3.18 mm). Probe tip **100**, at the free end of the smaller-diameter section **76*b*** of tip portion **76**, is illustrated in detail in FIG. **5** and described in the accompanying text.

Control rod **78** intrudes into an axial hole **82** drilled into the larger-diameter section **76*a*** of tip portion 76, where it is bonded, preferably using a heat-cured epoxy adhesive. The material of control rod **78** is selected to match the thermal expansion of the material of tip portion **76**; in the preferred embodiment control rod **78** is fabricated of titanium, which has a coefficient of thermal expansion sufficiently matched to that of alumina. In the present example, the diameter of control rod 78 is 0.062 in. (1.6 mm).

Prior to the insertion of the bonded assembly comprising control rod **78** and tip portion **76** into housing **48**, a compression spring **84** is slipped over the free end of control rod **78** where one end rests against the larger-diameter end of tip portion **76**. When this assembly is inserted within the central bore **70** of probe housing 48, the other end of spring **84** rests against shoulder **72** of central bore **70**. Spring **84** is selected such that while probe **40** is in its extended position, tip portion **76** exerts a force on the underlying circuit board of, illustratively, one pound.

Cap 80, preferably fabricated of titanium, has an axial hole **86** through which control rod **78** extends and is welded thereto. It will be recognized from the preceding paragraph that when cap **80** is welded to control rod **78**, spring **84** will be in compression within central bore **70**. Cap **80** includes a knurled surface **88** and recessed area **90** to enhance finger contact when manipulating plunger **74** for axial and rotational movement.

The portion of cap **80** adjacent housing **48** includes a fork-like structure **92** adapted to engage a mating structure in housing **48**. The fork-like structure **92** includes two tines having flat inner surfaces **94** which mate with corresponding flat surfaces **96** on housing **48**. This mating arrangement ensures that when plunger **74** is retracted by manually withdrawing cap **80** away from cover plate 32 against the compression forces of spring **84**, probe tip **100** will be lifted directly off the underlying circuit board without twisting. This arrangement also ensures correct placement of the tip **100** with respect to the printed wiring traces of the circuit board. In the retracted position, that is, when surfaces **94** of cap **80** are not in engagement with surfaces **96** of housing 84, the contact area of tip **100** is substantially aligned with the bottom (inner) surface of cover plate **32**.

Referring to FIG. **5**, there is shown an enlarged view of an illustrative probe tip **100**. The view of FIG. 5 includes a section **102** of the stepped-down cylinder of the alumina tip portion **76** of plunger **74** of FIG. **4**, and a contact tip **104**, which is illustratively a round alumina disk 0.050 in. (1.3 mm) thick and substantially equal in diameter to the diameter of section **102**. Contact tip 104 is spaced from section **102** by a layer **106** of a compliant material, illustratively a disk of 60 durometer butyl rubber 0.030 in. (0.76 mm) thick and substantially equal in diameter to the diameters of section **102** and contact tip **104**. Compliant layer **106** is fastened to the alumina portions **102** and **104** of probe **100** using suitable adhesive means, illustratively cyanoacrylate in the preferred embodiment.

Beveled surfaces **104*a***, **104*b***, **104*c*** and **104*d*** are formed on the exposed face of contact tip 104, thereby reducing the contact area **104*e*** to a small rectangle, typically 0.030 in. (0.76 mm) by 0.060 in. (1.5 mm). In the present example, surfaces **104***a*, **104***b*, **104***c* and **104***d* are beveled from surface **104***e* at an angle of approximately 25 degrees. The beveling of the exposed surface of contact tip **104** determines the position of the contact area **104***e* relative to the longitudinal (rotational) axis **98** (see FIG. **4**) of tip portion **76**. If contact tip **104** is beveled such that contact area **104***e* is symmetrical with respect to axis **98**, then rotation of plunger **74** to a fixed stop 180° away will not alter the position of contact area **104***e* relative to traces on the underlying circuit board. However, if contact tip **104** is beveled so as to produce a contact area **104***c* which is eccentrically placed with respect to axis **98**, then rotation of plunger **74** to a fixed stop 180° away will change the position of contact area **104***e* relative to the circuit board traces.

The rectangular area **104***e* at the end of contact tip **104** is made electrically conductive, typically by a gold plating **108**, the thickness of which is shown in highly exaggerated scale in FIG. **5**. Gold plating **108** is preferably electrodeposited on the flat contact area **104***e* and may illustratively be 600 angstroms in thickness. Compliant layer **106**, in conjunction with the one pound spring force described earlier, is sufficient to tilt contact tip **104** several degrees in order to align the contact area **104***e* with the surface of the circuit board and thereby ensure good electrical contact.

Ideally, probe **40** would apply a temporary jumper between printed wiring traces, via the plated contact tip **104**, without introducing any other material into the enclosure of the microwave housing. Within the purview of this invention, this goal is best achieved by the use of a slender non-conductive tip portion **76** fabricated of a material of low loss and low dielectric constant. In the preferred embodiment, alumina was selected for tip portion **76** over materials with superior electrical qualities because its high mechanical strength allows it to have a very small diameter. The correspondingly small volume of tip portion **76** more than compensates for the high relative dielectric value of this ceramic material. In addition, the butyl rubber selected for use in the preferred embodiment also has the characteristics of low loss and low dielectric constant.

In addition to the probes **40** described earlier, the present invention also includes a probe **200** having an additional level of complexity. In addition to having a probe tip with an eccentrically positioned contact tip, probe **200** further includes a rotatable internal housing providing eccentric positioning of the probe tip. With this arrangement, at least one additional position of contact of the probe tip with the underlying circuit board may be obtained.

Referring to FIG. **6**, there is shown a bottom view of probe **200**, illustrating the components which permit the tip of probe **200** to be located at least three distinct contact positions. Probe **200** includes a fixed external housing **202** attached to mounting flange **204**. Within fixed housing **202** is a rotatable housing **206**, and within rotatable housing **206** is a rotatable plunger **208**. Rotatable housing **206** and rotatable plunger **208** both include mating structures which engage fixed housing **202** so as to constrain their positions for which the probe tip is extended to two positions, each position being spaced apart by 180°.

As may be observed from FIG. **6**, the tip of plunger **208** is beveled so that contact area **210** is offset a small distance from the center of the tip. Furthermore, it will be observed that plunger **208** is offset a small distance from the central axis of rotatable plunger **206**. The effect of the first-mentioned offset, that of contact area **210** from the center of plunger **208**, as presently shown, is to shift the contact area **210** to the right when plunger **208** is rotated 180° with respect to rotatable housing **206**. The effect of the second-mentioned offset, that of plunger **208** from the center of rotatable housing **206**, as presently shown, is to shift contact area **210** to the left when rotatable housing **206** is rotated 180° with respect to fixed housing **202**. As will be understood, the total effect of these two offsets is to allow as many as four positions of contact area **210** with respect to the underlying circuit board. However, in the present embodiment, the firstmentioned offset is equal to the second-mentioned offset; thus, when plunger **208** is positioned such that contact area **210** is toward the left (as shown) and rotatable housing **206** is positioned such that plunger **208** is toward the right (as shown), rotation of both plunger **208** and rotatable housing **206** through 180° will result in effectively no lateral movement of contact area **210** with respect to an underlying circuit board.

Referring to FIG. **7**, there is shown a plan view of a portion of an MHIC module, depicting three hybrid modules **120**, **122** and **124**, and illustrating exemplary circuit traces and tuning patches adjacently located. By way of a first example, zone **130** depicts a printed wiring trace **132** and an adjacent patch **134** which may either be shorted together or remain unconnected in accordance with the tuning requirements of the circuit. In a second example, shown in zone **140**, circuit tuning may be effected by shorting just patch **142** or both patches **142** and **144** to the branch end comprising printed wiring trace **146**. Finally, a third example of tuning, shown in zone **150**, is accomplished by shorting either patch **152** or patch **154** or both patches **152** and **154** to circuit trace **156**.

Referring to FIGS. **8***a*–**8***c*, there are shown diagrams of specific examples of methods by which probes **40** and probe **200** of cover assembly **30** provide temporary jumpers between printed circuit wiring traces and printed circuit patches. FIG. **8***a* illustrates the position **160** of a temporary jumper which provides electrical continuity between printed circuit trace **162** and patch **164**. FIG. **8***b* illustrates the two positions **170** and **172** of a temporary jumper which provides, in a first position **170**, electrical contact between printed circuit trace **174** and patch **176**; and, in a second position **172**, contact among trace **174** and patches **176** and **178**. FIG. **8***c* illustrates the three positions **180**, **182** and **184** of a temporary jumper which provides, in a first position **180**, electrical contact between printed circuit trace **186** and patch **188**; in a second position **182**, contact between trace **186** and patch **190**; and, in a third position **184**, contact among trace **186** and patches **188** and **190**. In each of the cases illustrated by FIGS. *7a–7c*, the probe may be retracted so as to avoid any contact.

In the arrangement of FIG. **8***a*, the contact tip which provides the temporary jumper at position **160** is symmetrically placed with respect to the rotational axis **166** of the probe. Thus, when the probe of the FIG. **8***a* arrangement is rotated between its two locking positions 180° apart, it has effectively only one contact position **160**.

In the arrangement of FIG. **8***b*, the contact tip which provides the temporary jumper selectively at position **170** or at position **172** is asymmetrically placed with respect to the rotational axis **179** of the probe. Thus, the probe may be rotated to contact position **170**, shorting trace **174** to patch **176**; and it may be rotated an additional 180° to contact position **172**, shorting trace **174** to both patches **176** and **178**.

The arrangement of FIG. **8***c* employs a probe of the type shown as probe **200** (in FIG. **6**). The contact tip which provides the temporary jumper selectively at the first position **180**, the second position **182** or the third position **184** is asymmetrically placed with respect to the rotational axis **192** of the plunger and, in addition, the plunger includes a rotatable housing eccentrically positioned within the fixed housing mounted to the tuning cover. As a result, as the plunger and rotatable housing are rotated, the contact area moves with respect to the surface of the underlying circuit board. Thus, the probe may be located to contact position **180**, shorting trace **186** to patch **188**; by rotating either the plunger or the rotatable housing by 180°, the contact area is shifted down to contact position **182**, thereby shorting trace **186** to both patches **188** and **190**; and by rotating the other (as between the plunger and the rotatable housing) by 180°, the contact area is shifted further down to contact position **184**, thereby shorting trace **186** only to patch **190**.

The invention disclosed herein may be used in the production of microwave hybrid integrated circuit modules in accordance with the following illustrative procedure: cover assembly **30** is securely attached to housing **10** by tightening down screws **34**. Using a test setup for measuring the gain and noise figure, etc. of the MHIC module over the frequency range of interest, including, as an example, signal generators, noise source, noise figure meter, oscilloscope, frequency counter, amplifiers and power supplies (all not shown), the performance of the MHIC module is monitored. Probes **40** (and probe **200**) are manipulated, temporarily coupling various printed wiring patches to the printed wiring traces on the circuit board within the enclosed housing, and the effect on performance is observed. When a particular combination of probe jumper selections appears to provide satisfactory performance of the module, the positions of each of the probes is recorded and the cover assembly is removed. Permanent gold jumpers having substantially the same dimensions as the gold layers **106** of contact tips **104** of probes **40** (and probe **200**) are soldered to the circuit board traces according to the recorded data, and the conventional cover **12** is attached to housing **10**. Thus, the module tuning procedure, previously requiring many iterative steps involving attachment and removal of the housing cover, is completed after only one tuning step.

While the principles of the present invention have been demonstrated with particular regard to the illustrated structure of the figures, it will be recognized that various departures may be undertaken in the practice of the invention. The scope of this invention is not intended to be limited to the particular structure disclosed herein, but should instead be gauged by the breadth of the claims which follow.

What is claimed is:

1. A cover assembly for enclosing a housing, said housing container a printed wiring circuit board, said cover assembly comprising:

- a cover plate adapted for covering said housing, said cover plate having an aperture therethrough; and
- a probe extending through said aperture, said probe having an electrically conductive tip, said probe being movable between an extended position and a retracted position, said probe further including spring means biased so as to urge said probe to said extended position;
- wherein said extended position of said probe is adapted to locate said conductive tip in electrical contact with a printed wiring trace of said circuit board, and wherein said retracted position of said probe is adapted to withdraw said conductive tip away from said circuit board.

2. The cover assembly according to claim **1** further including means coupled to said cover plate for attaching said cover plate to said housing.

3. The cover assembly according to claim **1** wherein said cover plate has a plurality of apertures, said cover assembly further including a corresponding plurality of probes extending through said apertures, each of said plurality of probes having an electrically conductive tip and being movable between an extended position and a retracted position.

4. The cover assembly according to claim **1** wherein said conductive tip of said probe is adapted to provide an electrical path between said printed wiring trace on said circuit board and a printed tuning patch on said circuit board.

5. The cover assembly according to claim **4** wherein said probe is additionally movable to a second extended position, wherein said second extended position is adapted to locate said conductive tip of said probe so as to provide and electrical path between said printed wiring trace on said circuit board and a second tuning patch on said circuit board.

6. The cover assembly according to claim **5** wherein said probe is additionally movable to a third extended position, wherein said third extended position is adapted to locate said conductive tip of said probe so as to provide an electrical path among said printed wiring trace on said circuit board and said first-mentioned and said second tuning patches on said circuit board.

7. The cover assembly according to claim **1** further including means for moving said probe between said extended position and said retracted position, said moving means being located on the opposite side of said cover plate from said circuit board.

8. The cover assembly according to claim **1** wherein said probe includes means for providing efficacious contact between said conductive tip and said printed wiring trace.

9. The cover assembly according to claim **8** wherein said contact providing means includes means adapted to align said conductive tip against said printed wiring trace when said probe is urged to said extended position.

10. The cover assembly according to claim **1** wherein said probe has a generally cylindrical shape having a longitudinal axis, said probe comprising two coaxial rigid portions abutted to an intermediate compliant portion.

11. The cover assembly according to claim **10** wherein said two rigid portions of said probe are fabricated of a nonconductive ceramic material.

12. The cover assembly according to claim **11** wherein said ceramic material comprises alumina.

13. The cover assembly according to claim **10** wherein said compliant portion comprises butyl rubber.

* * * * *